

Parallel Outcomes

Comparing Effects of Environmental Contaminant Exposures with ADHD in Children

Attention deficit/hyperactivity disorder (ADHD), the most frequently diagnosed neurobehavioral disorder in children, affects more than 5% of the population worldwide. Although the etiology of ADHD is poorly understood, characteristics similar to those seen in children with ADHD also have been observed in



children and animals exposed to lead or polychlorinated biphenyls (PCBs). Two literature reviews in this issue provide an overview of ADHD diagnostic criteria and explore the parallels between behavioral test results from children with ADHD and findings from children and laboratory animals with developmental exposure to lead or PCBs [EHP 118(12):1646–1653; Aguiar et al.; EHP 118(12):1654–1667; Eubig et al.]. The authors conclude that exposure to these environmental contaminants, and possibly others, may increase the prevalence of ADHD.

Deficits in executive function and attention are key characteristics of both ADHD and developmental exposure to lead and PCBs. Executive func-

tion encompasses cognitive abilities critical to goal-oriented problem solving, such as working memory, response inhibition, cognitive flexibility (the ability to mentally “switch gears”), and planning.

Do Metals Meddle with Puberty in Girls?

Lead, Cadmium, and Altered Hormone Levels

Lead and cadmium are both known reproductive toxicants. Now researchers have identified a link between relatively low levels of these metals and hormone markers of delayed onset of puberty in girls [EHP 118(12):1782–1787; Gollenberg et al.].

A team of scientists led by researchers at the National Institute of Child Health and Human Development used blood samples collected from girls aged 6–11 years as part of the nationally representative Third National Health and Nutrition Examination Survey, conducted by the Centers for Disease Control and Prevention (CDC) between 1988 and 1994. The team measured concentrations of two reproductive hormones—inhibin B and luteinizing hormone—that serve as markers of hypothalamic, pituitary, and gonadal functioning.

Associations with lead were estimated for luteinizing hormone in 671 girls and inhibin B in 655 girls. Most of the girls whose hormones were measured had blood lead levels below the CDC’s 10- $\mu\text{g}/\text{dL}$ action level. The median blood lead level was 2.5 $\mu\text{g}/\text{dL}$, and less than 20% of the girls had blood lead levels exceeding 5 $\mu\text{g}/\text{dL}$. The median urinary cadmium concentration was 0.12 ng/mL (the authors considered levels over 0.27 ng/mL to be high). Non-Hispanic black girls had higher age-adjusted

Attention revolves around alertness (the ability to become alert and focus on a task) and vigilance (sustained alertness).

ADHD has a strong genetic component but, like other neurodevelopmental disorders, appears to involve interactions between genetic, environmental, and social factors. Neuroimaging studies in children with ADHD have revealed alterations in brain regions that control executive function and attention, such as the prefrontal cortex. Alterations in catecholamine neurotransmitter signaling also are present in children with ADHD. Such signaling is potentially susceptible to damage by environmental toxicants.

Developmental exposure to lead has been widely studied and is known to have a negative impact on cognitive function as well as on children’s behavior. Across studies, cognitive flexibility, vigilance, and alertness appear to be the functions most consistently affected by lead, but evidence also exists for negative effects on working memory, response inhibition, and planning. Several studies have reported associations between blood lead levels in children and ADHD.

In contrast, researchers are only just beginning to explore the relationship between PCB exposure and ADHD diagnosis. Developmental exposure to PCBs is known to affect cognitive functions including working memory, response inhibition, cognitive flexibility, and alertness, although there appears to be little if any impact on vigilance. Animal studies further show that both lead and PCBs can reduce dopamine (a catecholamine) signaling in the prefrontal cortex of the brain.

Although levels of lead and PCBs have declined overall in the environment and in our bodies, they remain public health issues. A better understanding of their roles in ADHD and other neurodevelopmental disorders is needed, and this knowledge could be useful in investigating other environmental agents including brominated flame retardants, bisphenol A, phthalates, organophosphate pesticides, and polyfluoroalkylated chemicals, all of which have been suggested by recent research to possibly be associated with ADHD.

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levels of both lead and cadmium than non-Hispanic whites or Mexican Americans.

The researchers found no significant associations with luteinizing hormone. However, girls aged 10 or 11 with blood lead levels of 5 $\mu\text{g}/\text{dL}$ or higher were 75% less likely than girls with blood lead under 1 $\mu\text{g}/\text{dL}$ to have levels of inhibin B greater than 35 pg/mL , a level typically deemed consistent with puberty by the limited research in this area. The researchers also found proportionately lower levels of inhibin B in girls who had relatively high levels of both cadmium and lead, compared with girls who had only high lead. Moreover, after adjusting for age, inhibin B levels were lowest for iron-deficient girls with blood lead levels of 1 $\mu\text{g}/\text{dL}$ or higher, suggesting that lead may be particularly toxic for girls with iron deficiency.

The authors conclude that lead may suppress the production of hormones associated with puberty, especially in concert with cadmium. They stress that, on a national scale, changes in the timing of onset and/or progression of puberty can have considerable public health and social implications for both boys and girls. For instance, relatively late-maturing girls are at risk for diminished bone strength and fragility fractures later in life. The hormone alterations linked to lead and cadmium exposure in the study also could have other as-yet unknown effects.

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Another Mechanism behind Cadmium Toxicity

Impaired NAT-Dependent Pathway Alters Chemical Biotransformation

Cadmium is a complex carcinogen that may contribute to carcinogenesis through multiple mechanisms, including inhibition of enzymes that help repair damaged DNA. A new study provides information on another possible mechanistic pathway by revealing that cadmium impairs NAT-dependent carcinogen metabolism as demonstrated by altered biotransformation of environmental aromatic amines (AAs) [EHP 118(12):1685–1691; Ragunathan et al.].

Cadmium accumulates in body tissues and causes disease of the lungs, kidneys, liver, testes, prostate, and bladder. It also is thought to potentiate the carcinogenicity of many common workplace chemicals. NATs, or arylamine *N*-acetyltransferases, are metabolic enzymes known to play a major role in the biotransformation of exogenous chemicals including AAs, many of which are known or suspected human carcinogens.

A Break in the Continuum

Analyzing the Gap in Particle Exposure Research

Researchers have examined the effects of fine particulate matter (PM_{2.5}) doses spanning nearly three orders of magnitude. Cardiovascular disease risks have been documented for active smoking exposures at the higher end of that continuum and for environmental tobacco smoke (ETS; sometimes called secondhand smoke) and ambient air pollution exposures at the lower end. However, there is a distinct lack of information on the cardiovascular risks of exposures in the middle range, which are experienced by hundreds of millions of people who burn biomass and coal indoors. A new commentary analyzes the implications of this crucial knowledge gap [EHP 118(12):1643–1645; Smith and Peel].

The authors note that plots of average inhaled doses of PM_{2.5} and associated cardiovascular health risks in the literature reveal a highly nonlinear exposure response. That is, exposure to ETS and ambient air pollution yield higher risks of heart disease than might be expected on the basis of exposure risks of active smokers.

Analysis of three intermediate estimated PM_{2.5} doses (inhaling 100 mg/day for a light smoker, 10 mg/day for a resident exposed to

In the current study the authors exposed purified NAT enzymes to cadmium and found the exposure led to rapid and irreversible functional impairment—removing the cadmium could not restore enzyme activities. They also exposed lung epithelial cells and laboratory mice to cadmium, then assessed NAT acetylation activity in the cells and mouse tissue samples. Biologically relevant concentrations of cadmium similar to those found in the lung tissue of heavy smokers impaired the NAT-dependent acetylation of carcinogenic AAs in lung epithelial cells, and NAT activity was strongly impaired in multiple tissues of mice exposed to cadmium.

These findings indicate acute cadmium exposure can alter the metabolism of carcinogenic AAs through impairment of the NAT-dependent pathway, with potentially important toxicologic effects—especially considering AAs are commonly found in cigarette smoke along with cadmium. The authors recommend further studies to address whether chronic cadmium exposure leads to similar effects.

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smoke from biomass burning, and 1 mg/day for someone exposed to ETS) similarly indicated that small PM_{2.5} dose reductions in populations with relatively low levels of exposure may achieve greater health gains than more drastic reductions in populations with high levels of exposure. Comparing a theoretical population of smokers with the same number of nonsmokers living in a heavily polluted city, this suggests similar numbers of cardiovascular deaths—or possibly more—may be prevented in the nonsmokers by adopting strict ambient PM_{2.5} reduction measures than by convincing the smokers to quit smoking. This counterintuitive idea could have major policy ramifications, so the authors urge further examination of these relationships.

The gap in studies of exposures greater than those from ETS but less than those from active smoking reflects a dose range of 1–20 mg/day. Filling in the missing information for this gap should receive research priority, the authors write, because of the potentially large cardiovascular disease health burden it represents, particularly for the people worldwide who burn biomass for household cooking and heating.

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The health effects of particulate exposure through active and passive smoking have been studied extensively. Less is known about similar exposures that result from indoor biomass and coal burning, a part of daily life for hundreds of millions of people worldwide.